Marine Physical Laboratory

Electric Fields Induced by Turbulence in the Seabed Boundary Layer

Spahr Webb and Charles Cox

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Abstract

The objective of this research was to describe and understand the electrical fluctuations that occur in a turbulent bottom boundary layer in shallow water. In the enviroment voltage fluctuations are produced not only by induction from large scale sources such as geomagnetic disturbances in the upper atmosphere, but also by small scale local processes including inducting from turbulent eddies and sea surface waves, and streaming potentials developed in seafloor sediments. In working towards this objective we have installed an array of electric and pressure detectors in the Strait of Juan de Fuca where a strong field stream generates a well defined bottom boundary layer, and wave action in a winter is expected to modify the layer. Theoretical studies were made to model the electric field based on models for vorticity fluctuations of water velocity in a turbulent boundary layer.

Research Summary

Electric fields are induced at the seafloor by the motion of seawater through the Earth's magnetic field. Ocean waves, seismoacoustic waves, and turbulence are all sources of field fluctuations in shallow water. The

goal of the project was to investigate the induction of electric fields by the turbulent motion of seawater in the bottom boundary layer.

A 20 m aperture hexagonal array of 30 pressure sensors and 39 electric field sensing electrodes was constructed and deployed on the seabed in March, 1994 from the R/V Thompson at a depth of 110 m, near the mouth the Straits of Juan de Fuca. A strong tidal current generates a deep boundary layer over this site. Pressure and field fluctuations were recorded over 8 months duration on two independent recording systems within a pressure case mounted with the array. The array was recovered from the R/V New Horizon in September, 1995. Limited ship funds had required us to deploy the array on an extremely rushed schedule to fit the R/V Thompson sailing schedule with no opportunity to test the array before deployment. During analysis we soon discovered the outermost ring of six pressure sensors on the array had failed after the array was deployed as the large capacitance associated with the long cabling caused the output amplifiers to oscillate once the sensors were underwater. The other 63 sensors in the array had worked, but signals from these sensors were partly contaminated by noise electrostatically coupled from the failing sensors. After several more months of work it become clear that it was not possible to remove these signals from the electric field data sufficiently to obtain useful measurements of the very small signals associated with the turbulence.

We decided after consultations with the program manager to rebuild the array, fix the problem and redeploy the array during a cruise of opportunity off Eureka, California in August, 1996. This is an open ocean site, with large waves, and much weaker currents than the Straits of Juan de Fuca site. It is a more typical site than the site in the straits, representing an average continental shelf regime. The new site also changed the focus of the experiment from sea bed turbulence to the complicated nonlinear interaction of ocean waves, and the induction of electric fields. The more energetic ocean wave climate required a reconfiguration of the pressure sensors to prevent clipping at low frequencies. The array was deployed on August 6, 1996 using the R/V Wecoma, and recovered using the R/V New Horizon on September, 29, 1996. A mooring with two current meters was deployed at a distance of 100m from the seafloor array to provide a record of current during the deployment and to serve as a marker buoy to protect the array from trawlers. A WHOI BASS sensor tripod was deployed nearby from the R/V McGaw a few days after the main array deployment. The BASS tripod and the current mooring were also recovered during the New Horizon cruise.

Analysis to date shows good data was obtained from all but a few of the 69 sensors. The BASS sensor data and current meter data show low mean currents during the experiment. The pressure spectra show ocean waves dominate below 0.12 Hz, with interval at slightly higher frequencies controlled by wave-wave interaction signals. The signals above 0.5 Hz appear to be controlled by turbulence with very low frequencies (<.05 Hz) controlled by infragravity wave signals. The pressure spectra from individual sensors are extremely similar with near perfect coherence in the ocean wave band. Electric field observations show coherence with pressure data at most frequencies, but the coherence varies considerably with time, as expected if the signals are controlled by current or a changing wave climate. Analysis of a earlier electric field and pressure array experiment demonstrated the importance of wave-wave interaction signals in determining the pressure and electric fields at frequencies above ocean wave frequencies for measurements on the shelf (R. Prescott, in preparation). We are continuing analysis of this data using private funds.

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